CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

STCW 78 as amended SMALL VESSEL CHIEF ENGINEER <3000 GT, <9000 kW UNLIMITED

058-11 - GENERAL ENGINEERING SCIENCE I

FRIDAY, 27 JUNE 2025

1400 - 1600 hrs

Materials to be supplied by examination centres

Candidate's examination workbook
Graph paper

Examination Paper Inserts

Notes for the guidance of candidates:

1. Examinations administered by SQA on behalf of the Maritime & Coastguard Agency.

2. Candidates are required to obtain 50% of the total marks allocated to this paper to gain a pass AND also obtain a minimum 40% in Sections A and B of the paper.

3. Non-programmable calculators may be used.

4. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Maritime &
Coastguard
Agency

SQA

GENERAL ENGINEERING SCIENCE I

Attempt ALL questions.

Marks for each question are shown in brackets.

Section A

1. (a) Simplify the following giving your answer in the simplest mixed number format.

$$x = \left(9\frac{5}{8} \div 1\frac{3}{4}\right) - 2\frac{2}{3}$$

(4)

   (b) Determine the value of 'n' using logarithms in the following expression when $P_2 = 2 \times P_1$ and $T_1 = 2.5 \times T_2$:

$$P_1 T_1^n = P_2 T_2^n$$

(4)

2. Simplify EACH of the following and rearrange to make x the subject of the expression:

   (i) $y = \frac{x^3}{x^2} \times \frac{x^4}{4y}$

(4)

   (ii) $y = \frac{x^2 \times z^3}{z^2} \div \frac{x^3 \times yz}{x^2}$

(4)

3. A function is given by the equation $y = 2.5\,x^2 + 1$.

   (a) Determine a table of data for the range x = -2 to x = 2 showing the method used.

(4)

   (b) Sketch a graph of the data determined in Q3(a).

(4)

   (c) From the graph estimate the value for x when y = 5.

(2)

[OVER

4. A,B,C and D are shown in Fig Q4. Determine the shortest distance between A and D. (8)

B

0.6

A

D

0.7

0.4

a   b
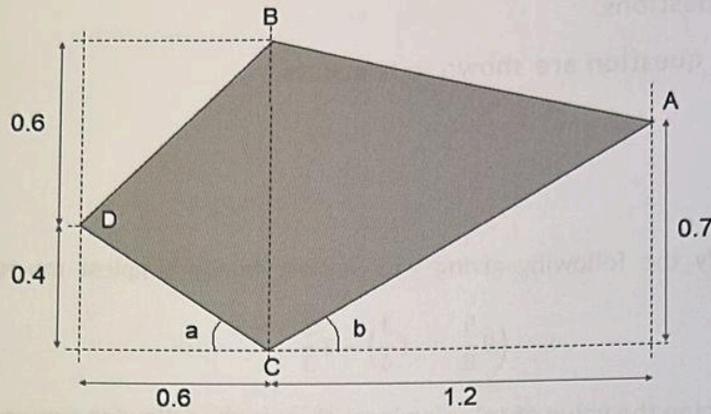
C

0.6   1.2

Fig Q4 (not to scale)

5. (a) Define the term scalene triangle. (2)

    (b) For the shape shown in Fig Q5 determine the angle MBD describing your reasoning. (6)

e
H
I
S

A   D

46°

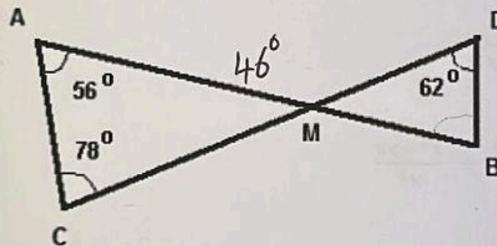56° 62°

M

78° B

C

Fig Q5

6. A cone is to be cast from aluminium with base diameter of 80 mm and a height of 7 cm. Cubes of aluminium, 1 cm³ are available to make the casting.

Aluminium has a density of 2.6 tonnes/m³.

    (a) Determine the minimum number of cubes that will be needed to make the cone. (5)

    (b) Determine the mass of the cone. (3)

Section B

7.   A vehicle starts from rest and accelerates with constant acceleration of 1.5 m/s²
     to a speed of 7.0 m/s. It then travels at 7 m/s for 25 seconds after which it is
     retarded to a speed of 1 m/s. if the complete motion takes 44.5 seconds:

     (a) Sketch the velocity/time diagram.   (2)

     (b) Determine EACH of the following:

          (i)   the time taken to reach 7 m/s;   (3)

          (ii)   the retardation (Deceleration);   (3)

          (iii) the total distance travelled.   (2)

8.   The beam loaded as shown in FIG Q8 has a uniform cross section and a total mass
     of 200 kg. Determine the mass, M, required to balance the beam on the
     fulcrum, F.   (8)
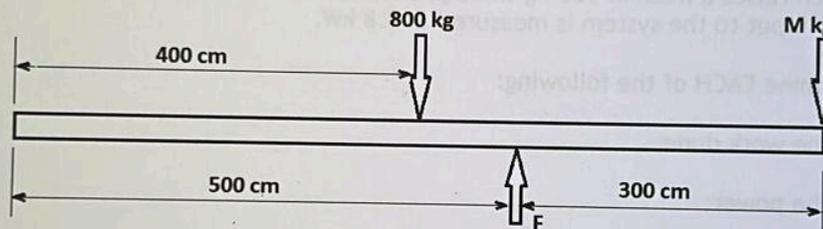

FIG Q8 (not to scale)

9.   A worm and wheel gear has an overall efficiency of 82%. The worm has a single
     start thread and carries an effort pulley with a diameter, d = 40 mm. The wheel
     has 160 teeth and a load pulley of diameter, D = 150 mm.

     (a) Sketch the arrangement described.   (2)

     (b) Determine EACH of the following:

          (i)   the velocity ratio;   (2)

          (ii)   the force ratio;   (2)

          (iii) the effort required to lift a load of 1000kg.   (2)

[OVER

10. A stationary object with a mass of 25 kg has a force of 140 N applied to it which causes acceleration in a horizontal plane. The coefficient of friction between the body and the plane is 0.35.

Determine EACH of the following:

(a) the acceleration of the body;   (4)

(b) the distance the body will travel from rest in 6 seconds.   (4)

11. A steel sheet 3 mm thick requires a round hole, 40 mm diameter, to be punched through it. If the metal has a shear strength of 180 MPa.

Determine EACH of the following:

(a) the minimum force required to punch the hole;   (4)

(b) the maximum compressive stress on the punch during this process.   (4)

12. A winch raises a mass of 920 kg through a distance of 9.6 m in 45 seconds. The power input to the system is measured at 3.8 kW.

Determine EACH of the following:

(a) the work done;   (3)

(b) the power;   (3)

(c) the system efficiency.   (2)

1. (a) Simplify the following giving your answer in the simplest mixed number format.

$$x = \left(9\frac{5}{8} \div 1\frac{3}{4}\right) - 2\frac{2}{3}$$

(4)

$$\left(9\frac{5}{8} \div 1\frac{3}{4}\right) - 2\frac{2}{3}$$

$$\left(\frac{77}{8} \div \frac{7}{4}\right) - \frac{8}{3}$$

$$\frac{11}{2} \frac{\cancel{77}}{\cancel{8}} \times \frac{\cancel{4}}{\cancel{7}}$$

$$\frac{3 \times 11}{3 \times 2} - \frac{8 \times 2}{3 \times 2}$$

$$\frac{33}{6} - \frac{16}{6} = \frac{17}{6} = 2\frac{5}{6}$$

(b) Determine the value of 'n' using logarithms in the following expression when
$P_2 = 2 \times P_1$ and $T_1 = 2.5 \times T_2$:

$$P_1 T_1^n = P_2 T_2^n \qquad (4)$$

$P_2 = 2P_1$ $\qquad\qquad$ $T_1 = \dfrac{5}{2} T_2$

$$P_1 \left(T_1\right)^n = P_2 \left(T_2\right)^n$$

$$P_1 \left(\frac{5}{2} T_2\right)^n = 2P_1 \left(T_2\right)^n$$

$$\left(\frac{5}{2} T_2\right)^n = 2 \left(T_2\right)^n$$

$$\frac{\left(\frac{5}{2}\right)^n \left(T_2\right)^n}{\left(T_2\right)^n} = 2$$

$$\log_{\frac{5}{2}} \left(\frac{5}{2}\right)^n = \log_{\frac{5}{2}} 2$$

$$n = \log_{\frac{5}{2}} (2)$$

$$n = 0.756471$$

2. Simplify EACH of the following and rearrange to make x the subject of the expression:

(i) $y = \frac{x^3}{x^2} \times \frac{x^4}{4y}$ (4)

(ii) $y = \frac{x^2 \times z^3}{z^2} \div \frac{x^3 \times yz}{x^2}$ (4)

i) $y = \frac{x^3}{x^2} \times \frac{x^4}{4y}$

$y = \frac{x^{7} \cdot 5}{\not{x}^{4} 4y}$

$y = \frac{x^5}{4y}$

$4y^2 = x^5$

$\sqrt[5]{4y^2} = x$

ii) $y = \frac{x^2 z^3}{z^2} \div \frac{x^3 y z}{x^2}$

$y = \frac{x^2 z^3}{z^2} \times \frac{x^2}{x^3 y z}$

$y = \frac{x^4 z^3}{x^3 y z^3}$

$y = \frac{x}{y}$

$y^2 = x$

3.   A function is given by the equation $y = 2.5 x^2 + 1$.

(a) Determine a table of data for the range x = -2 to x = 2 showing the method used.   (4)

(b) Sketch a graph of the data determined in Q3(a).   (4)

(c) From the graph estimate the value for x when y = 5.   (2)

a)

x	$y = 2.5x^2 + 1$
-2	$2.5(-2)^2 + 1 = 11$
-1	$2.5(-1)^2 + 1 = 3.5$
0	$2.5(0)^2 + 1 = 1$
1	$2.5(1)^2 + 1 = 3.5$
2	$2.5(2)^2 + 1 = 11$

b)

c) when $y = 5$

$x = -1.25$

$x = +1.25$

4.   A,B,C and D are shown in Fig Q4. Determine the shortest distance between A and D.
(8)

B

0.6

A

0.7

0.4

a   b

C

0.6   1.2

Fig Q4 (not to scale)
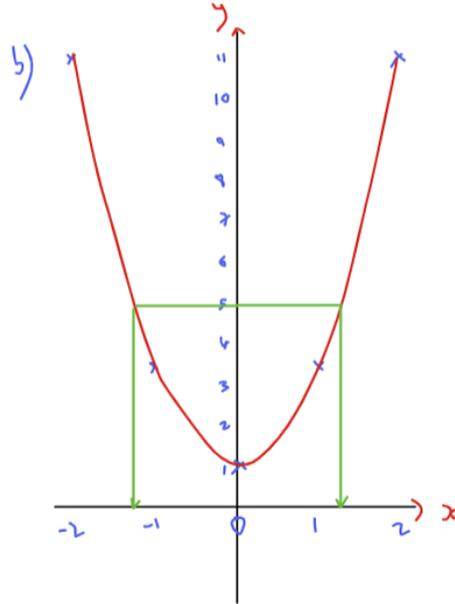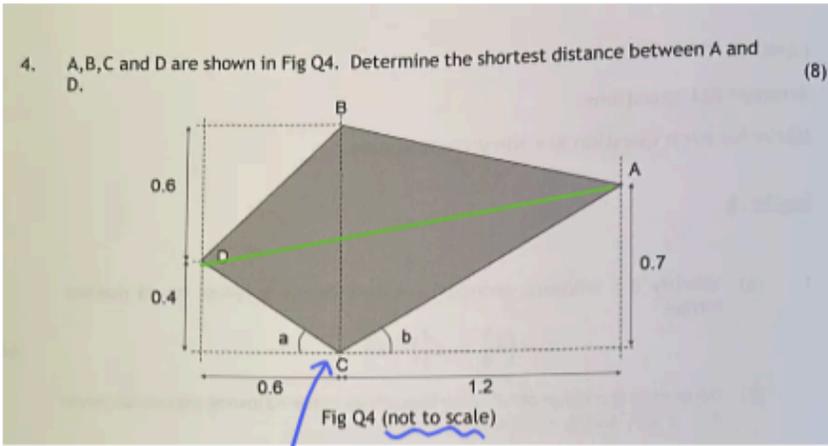
I will assume this is a straight line, as no angles are given

0.4

0.7

0.6   1.2

← Assume 90°

0.4

0.7

0.6   1.2

1.8

x

0.3

1.9
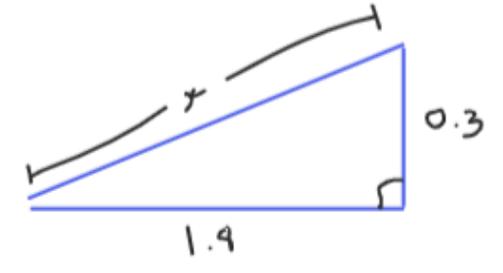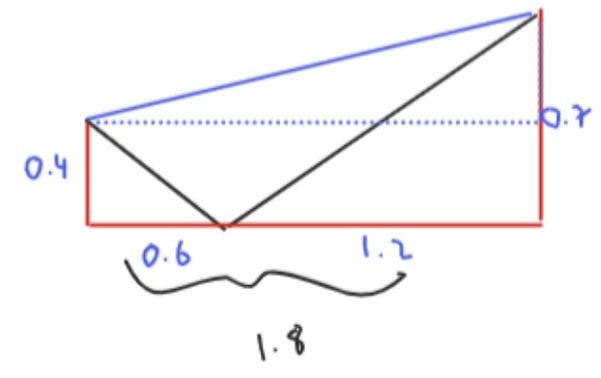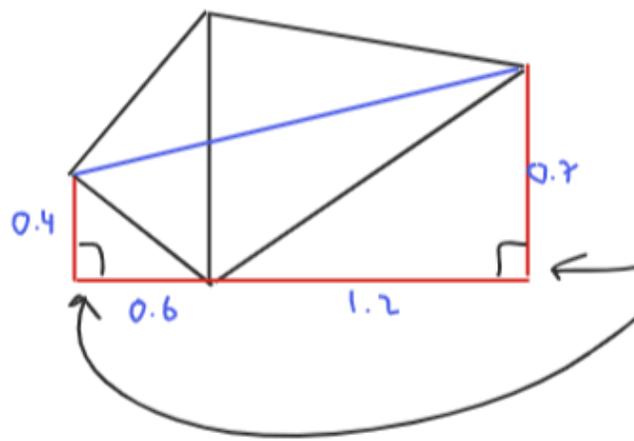
$\sqrt{1.8^2 + 0.3^2} = x$

1.82493 units = x

5.   (a) Define the term scalene triangle.   (2)

     (b) For the shape shown in Fig Q5 determine the angle MBD describing your
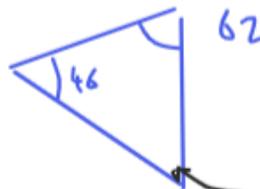   reasoning.   (6)

e
H
I
S

A 46° D

56^0 62^0

78^0 M

C   B

Fig Q5

56   62

78
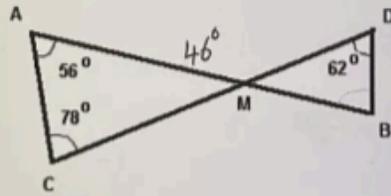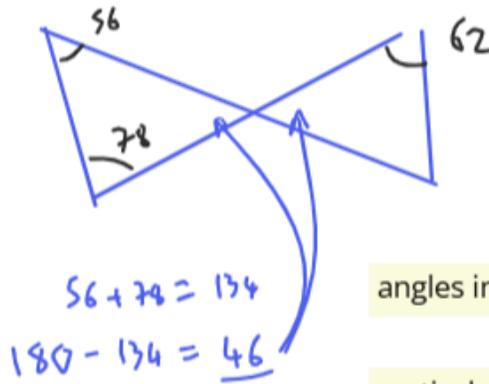
$56 + 78 = 134$ angles inside of a triangle sum to 180 degrees

$180 - 134 = 46$

                          vertical angles have the same measure

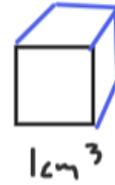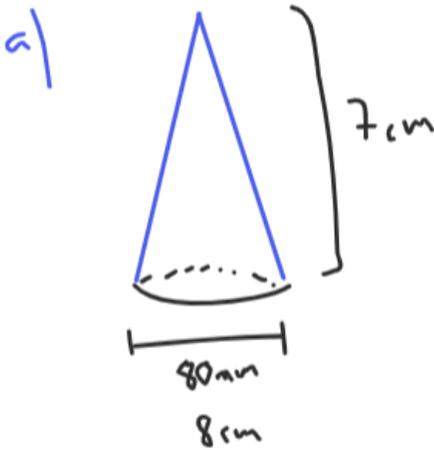46   62 $62 + 46 = 108$

                    $180 - 108 = 72^\circ$

Angle MBD $= 72^\circ$

6. A cone is to be cast from aluminium with base diameter of 80 mm and a height of 7 cm. Cubes of aluminium, 1 cm³ are available to make the casting.

Aluminium has a density of 2.6 tonnes/m³.

(a) Determine the minimum number of cubes that will be needed to make the cone.

(5)

(b) Determine the mass of the cone.

(3)
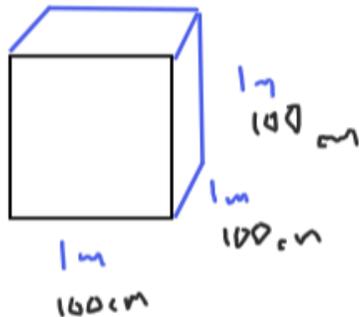
a)

7 cm

1cm³

80mm

8cm

$$Vol = \frac{\pi R^2 h}{3} = \frac{\pi \, 4^2 \cdot 7}{3} = 117.286 \, cm^3$$

Need 118 cubes

b) $117.286 cm^3$

$d = 2600 \, kg/m^3$

$1m^3 = (100 \times 100 \times 100)$

$1m^3 = 1,000,000 \, cm^3$

$\div 10^6$
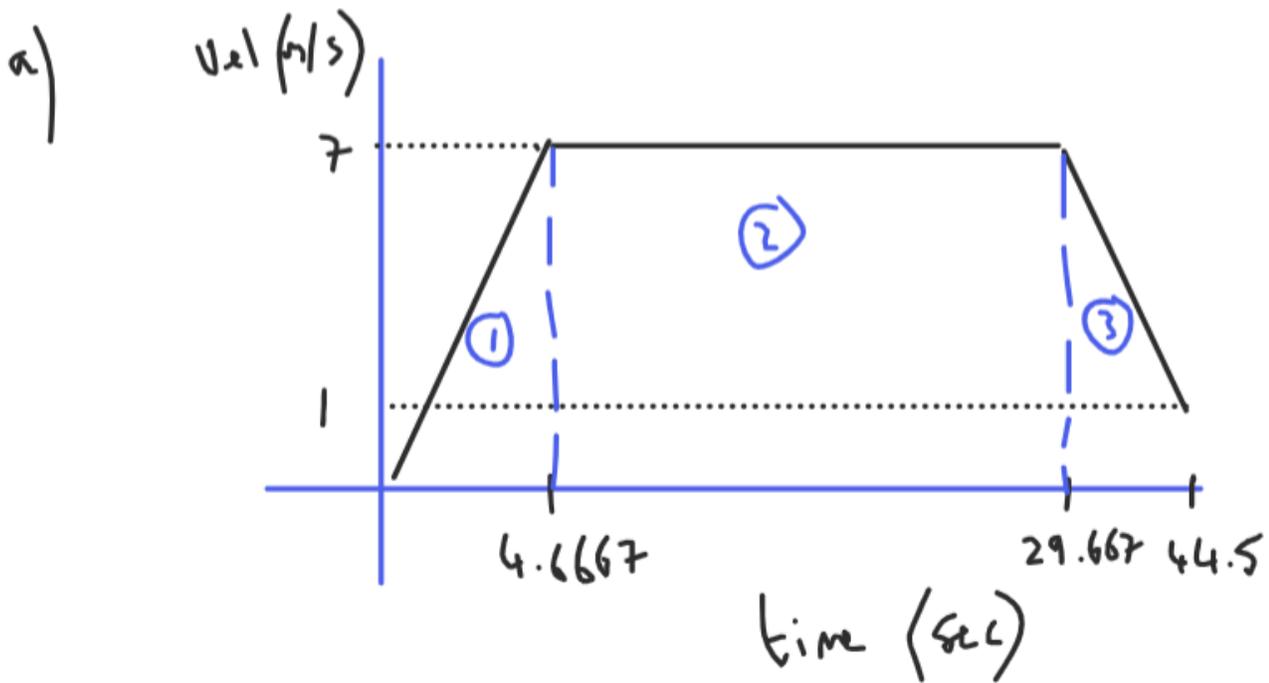
$$\frac{117.286}{1,000,000} = 1.17268 \times 10^{-4} \, m^3$$

$m = d \times v$

$= 2600 \times 1.17268 \times 10^{-4}$

$= \boxed{0.3048968 \, Kg}$

7. A vehicle starts from rest and accelerates with constant acceleration of 1.5 m/s²
    to a speed of 7.0 m/s. It then travels at 7 m/s for 25 seconds after which it is
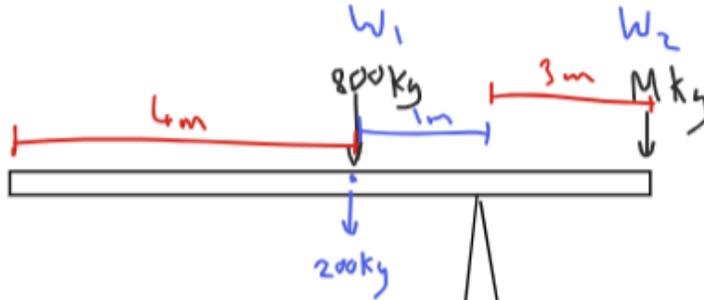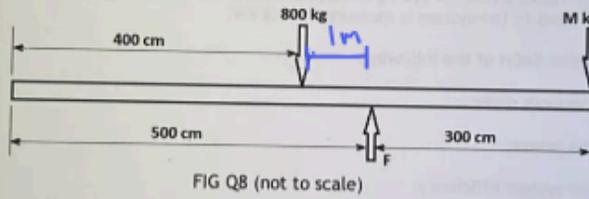   retarded to a speed of 1 m/s. if the complete motion takes 44.5 seconds:

    (a) Sketch the velocity/time diagram.   (2)

    (b) Determine EACH of the following:

        (i)   the time taken to reach 7 m/s;   (3)

        (ii)   the retardation (Deceleration);   (3)

        (iii) the total distance travelled.   (2)

a)

① ② ③

$S =$
$u = 0$
$v = 7 \, m/s$
$a = 1.5 \, m/s^2$
$t = x = 4.6667 \, sec$

$S =$
$u = 7$
$v = 7$
$a = 0$
$t = 25$

$S =$
$u = 7$
$v = 1$
$a = x$
$t = 14.8333$

Find t
$v = u + at$

$7 = 0 + 1.5x$

$\dfrac{7}{1.5} = x$

a) $4.66667 \, sec$

$44.5 - 29.6667 = 14.8333 \, sec$

Find a

$V = u + at$

$1 = 6 + 14.8333x$

$\dfrac{-6}{14.8333} = x$

$-0.404494 \, m/s^2$

b) $0.404494 \, m/s^2$

Find s

$s = \left(\dfrac{u+v}{2}\right) t$

$s = \left(\dfrac{0+7}{2}\right) 4.6666$

16.3333

$\left(\dfrac{7+7}{2}\right) 25$

175

$\left(\dfrac{7+1}{2}\right) 14.8333$

59.3333

c) total $= 250.666 \, m$

8.   The beam loaded as shown in FIG Q8 has a uniform cross section and a total mass of 200 kg. Determine the mass, M, required to balance the beam on the fulcrum, F.

```
                         800 kg                    M kg
           400 cm         ↓  1m                      ↓
        ├──────────────┤ ╥├──┤                       ╥
        ┌─────────────────────────────────────────────┐
        └─────────────────────────────────────────────┘
        ├─────────────500 cm──────────┤△├──300 cm──────┤
                                       F
                    FIG Q8 (not to scale)
```


$$W_1 \qquad\qquad W_2$$
$$800kg \qquad 3m \quad M kg$$
$$4m \qquad\qquad 1m$$

$$200kg$$

$$\frac{Beam}{2} - overhang$$

$$\frac{8}{2} - 5 = -1$$

taking moments about fulcrum

Name	Mass (kg)	Force (N)	Dis (m)	Moment (Nm)	Di $\langle A/c \rangle$
W_1	800	7848	1	7848	C
W_2	x	$9.81x$	3	$29.43x$	A
Beam	200	1962	1	1962	C

Sum of clockwise moments = Sum of anticlockwise moments

$$7848 + 1962 = 29.43x$$

$$9810 = 29.43x$$

$$\boxed{333.333 \ kg} = x = W$$

9.   A worm and wheel gear has an overall efficiency of 82%. The worm has a single start thread and carries an effort pulley with a diameter, d = 40 mm. The wheel has 160 teeth and a load pulley of diameter, D = 150 mm.

   (a) Sketch the arrangement described.   (2)

   (b) Determine EACH of the following:

       (i)   the velocity ratio;   (2)

       (ii)   the force ratio;   (2)

       (iii) the effort required to lift a load of 1000kg.   (2)

10. A stationary object with a mass of 25 kg has a force of 140 N applied to it which causes acceleration in a horizontal plane. The coefficient of friction between the body and the plane is 0.35.

   Determine EACH of the following:

   (a) the acceleration of the body;   (4)

   (b) the distance the body will travel from rest in 6 seconds.   (4)

a)

25kg / 140N

mg
25 × 9.81
245.25 N
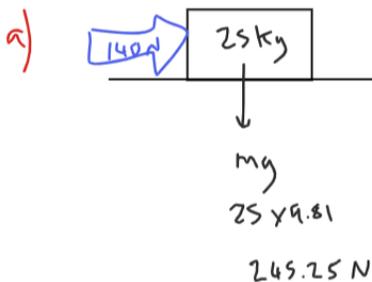
Friction = μN

= 0.35 × 245.25

= 85.8375 N

Net Horiz

Push − Fric

140 − 85.8375 = 54.1625

Accel   F = ma

54.1625 = 25x

$\dfrac{54.1625}{25}$ = x

2.1665 m/s²

b)

$$S = x$$
$$y = 0$$
$$v$$
$$a = 2.1665 \ m/s^2$$
$$t = 6$$

$$v = u + at$$

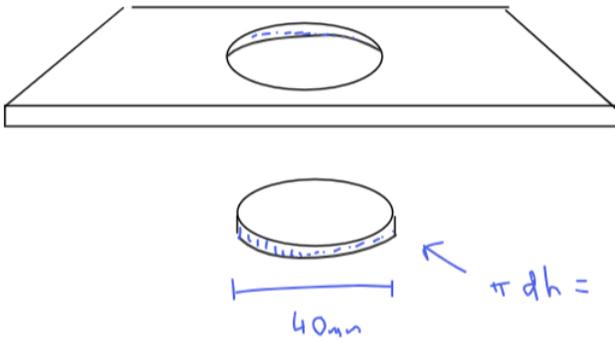$$S = ut + \frac{1}{2}at^2$$

$$x = \cancel{u6} + 0.5(2.1665)6^2$$

$$= \boxed{38.997 \ m}$$

11. A steel sheet 3 mm thick requires a round hole, 40 mm diameter, to be punched through it. If the metal has a shear strength of 180 MPa.

Determine EACH of the following:

(a) the minimum force required to punch the hole;   (4)

(b) the maximum compressive stress on the punch during this process. (4)

40mm

$\pi dh =$

a) $stress = \dfrac{F}{A}$

$stress = 180,000,000 \; (Pa)$

N/m^2

in metres

$A = \pi dh$

$A = \pi (0.04)(0.003)$

$= 3.7699 \times 10^{-4} \; m^2$

Stress $\times$ Area $=$ Force

$180,000,000 \times 3.7699 \times 10^{-4} =$

$\boxed{67,858.4 \; N = Force}$
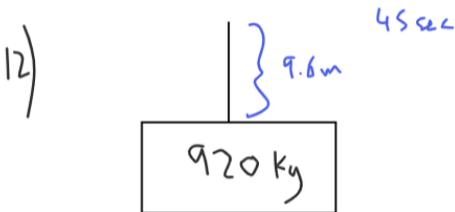
$6.7 \; t \quad \underline{ok!}$

12. A winch raises a mass of 920 kg through a distance of 9.6 m in 45 seconds. The power input to the system is measured at 3.8 kW.

Determine EACH of the following:

(a) the work done;   (3)

(b) the power;   (3)

(c) the system efficiency.   (2)

12)

45 sec

9.6m

920 kg

$P = \dfrac{mgh}{t} = \dfrac{920 \times 9.81 \times 9.6}{45} = \dfrac{86,641.92 \; J}{45 \, sec}$

a) 86,641.92 Joules

b) 1925.376 Watts

c) $Eff = \dfrac{1925.376}{3800} \times 100 = 50.6678 \%$